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The potential role of flexible CCS in deep decarbonization of the electricity sector

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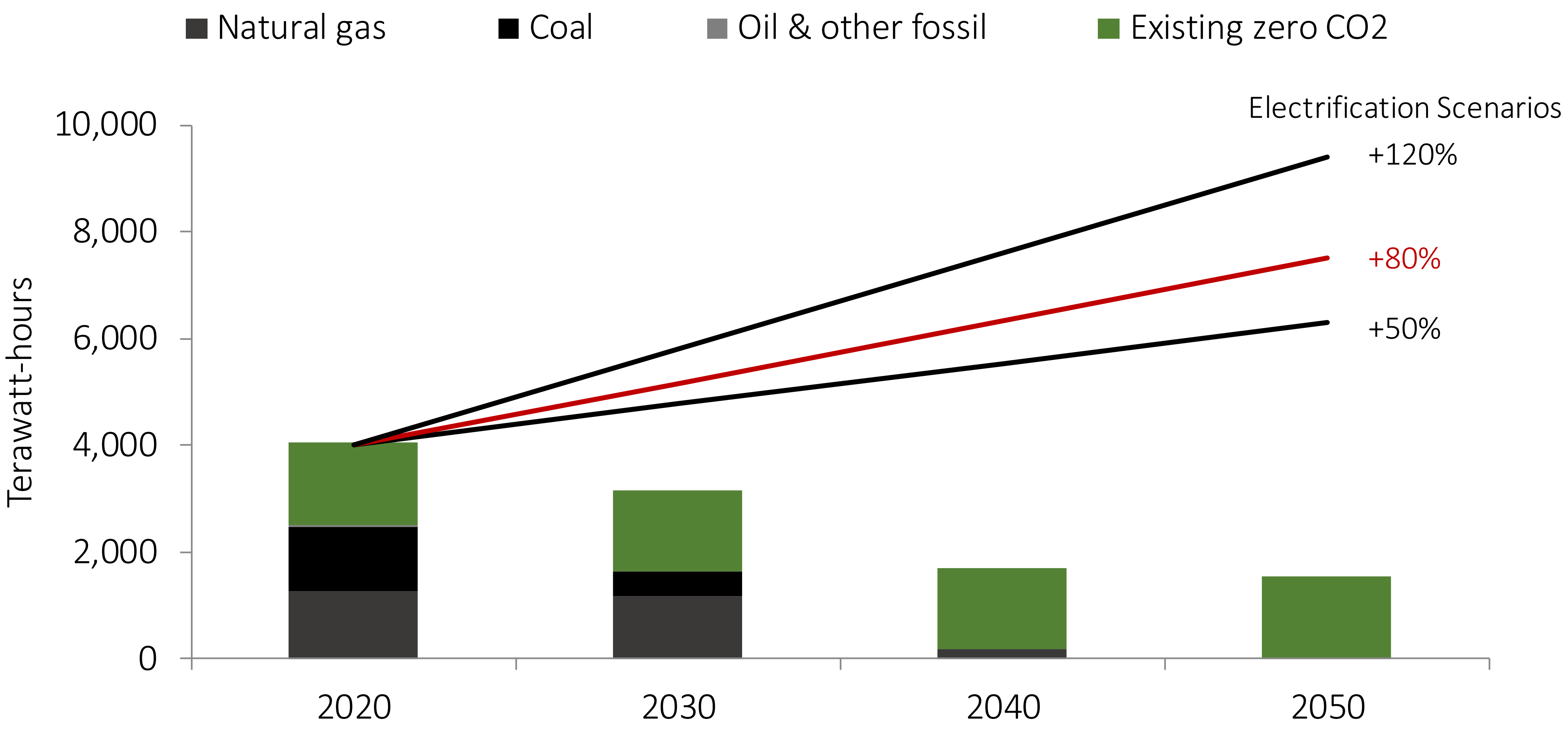
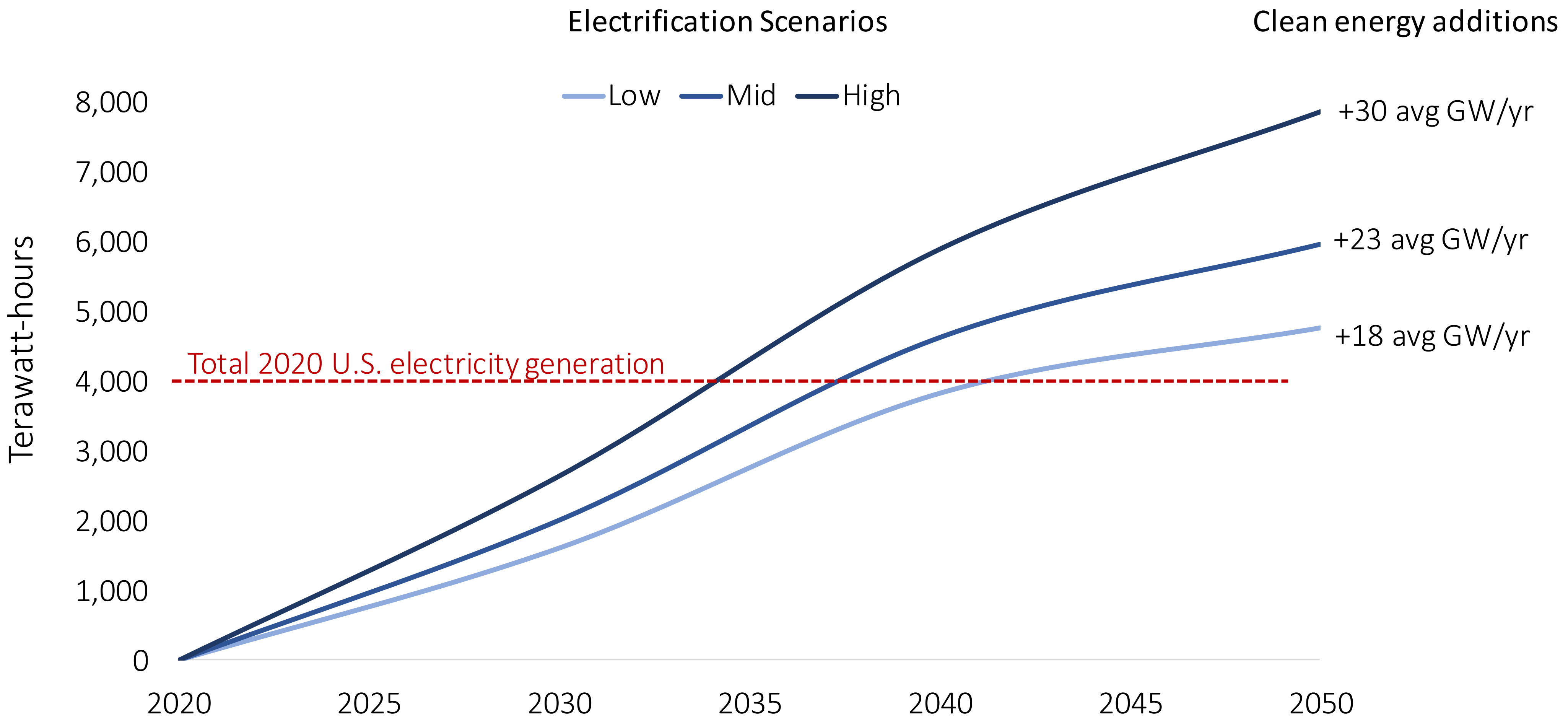
“Flexible Carbon Capture Technologies for a Renewable-Heavy Grid,” ARPA-E Workshop | July 30, 2019

TWIN CHALLENGES: ZERO CARBON, DOUBLE DEMAND



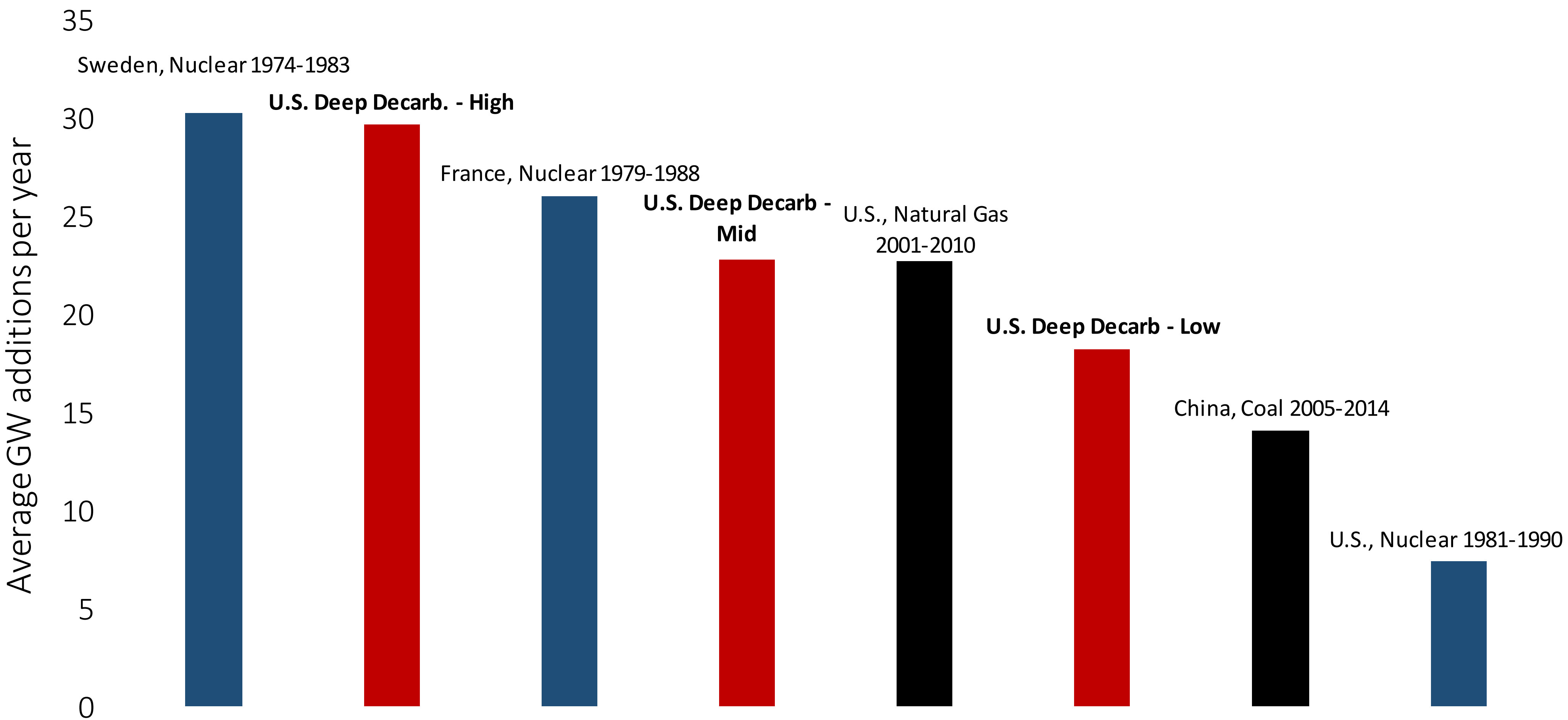
Data source: Iyer et al. 2017, GGCAM USA Analysis of U.S. Electric Power Sector Transitions (performed for the United States Mid-Century Strategy for Deep Decarbonization), Pacific Northwest National Laboratory; 2020 zero-carbon electricity supply from EIA Annual Energy Outlook 2019.

THE RAPID SWITCH: NEW ZERO CARBON ELECTRICITY NEEDED



Data source: Difference between projected electricity demand in Iyer et al. 2017 and 2020 zero-carbon electricity supply from EIA Annual Energy Outlook 2019. Assumes all 2020 generation can be sustained through 2050. Retirements of existing capacity would increase new zero-carbon generation needed.

HISTORICAL PRECEDENTS (SCALED TO U.S. POPULATION)



Data source: Historical per capita deployment rates from MIT 2018, The Future of Nuclear in a Carbon Constrained World, scaled to based on projected 2035 U.S. population of 364 million from U.S. Census Bureau.

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The Role of Firm Low-Carbon Electricity Resources in Deep Decarbonization of Power Generation

Nestor A. Sepulveda [4] • Jesse D. Jenkins • Fernando J. de Sisternes • Richard K. Lester •

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http://bit.ly/FirmLowCarbon

PlumX Metrics

Highlights

Summary

Graphical Abstract

Keywords

References

Article Info

Highlights

- Firm low-carbon resources consistently lower decarbonized electricity system costs
- Availability of firm low-carbon resources reduces costs 10%–62% in zero-CO_2 cases
- Without these resources, electricity costs rise rapidly as CO_2 limits near zero

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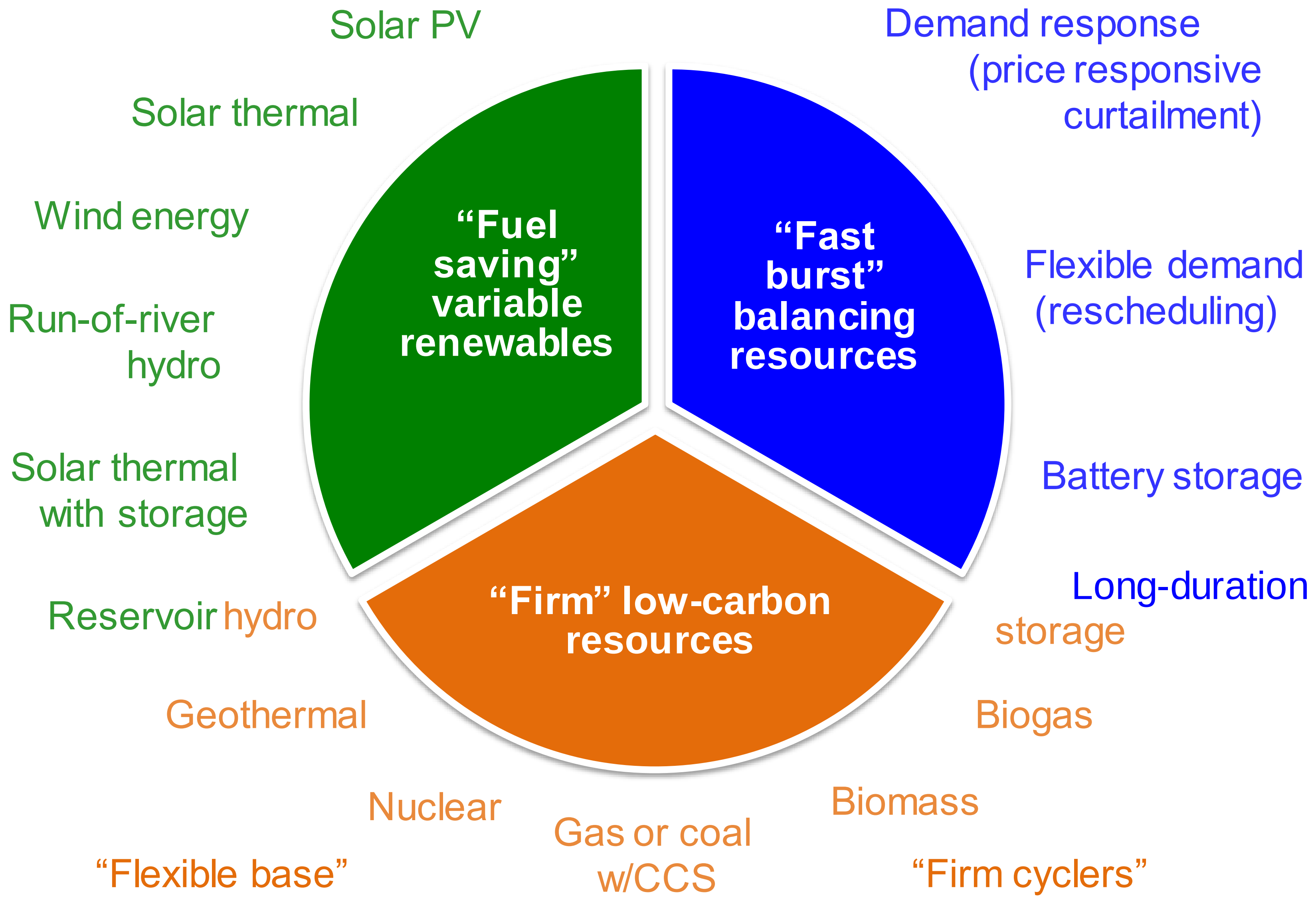
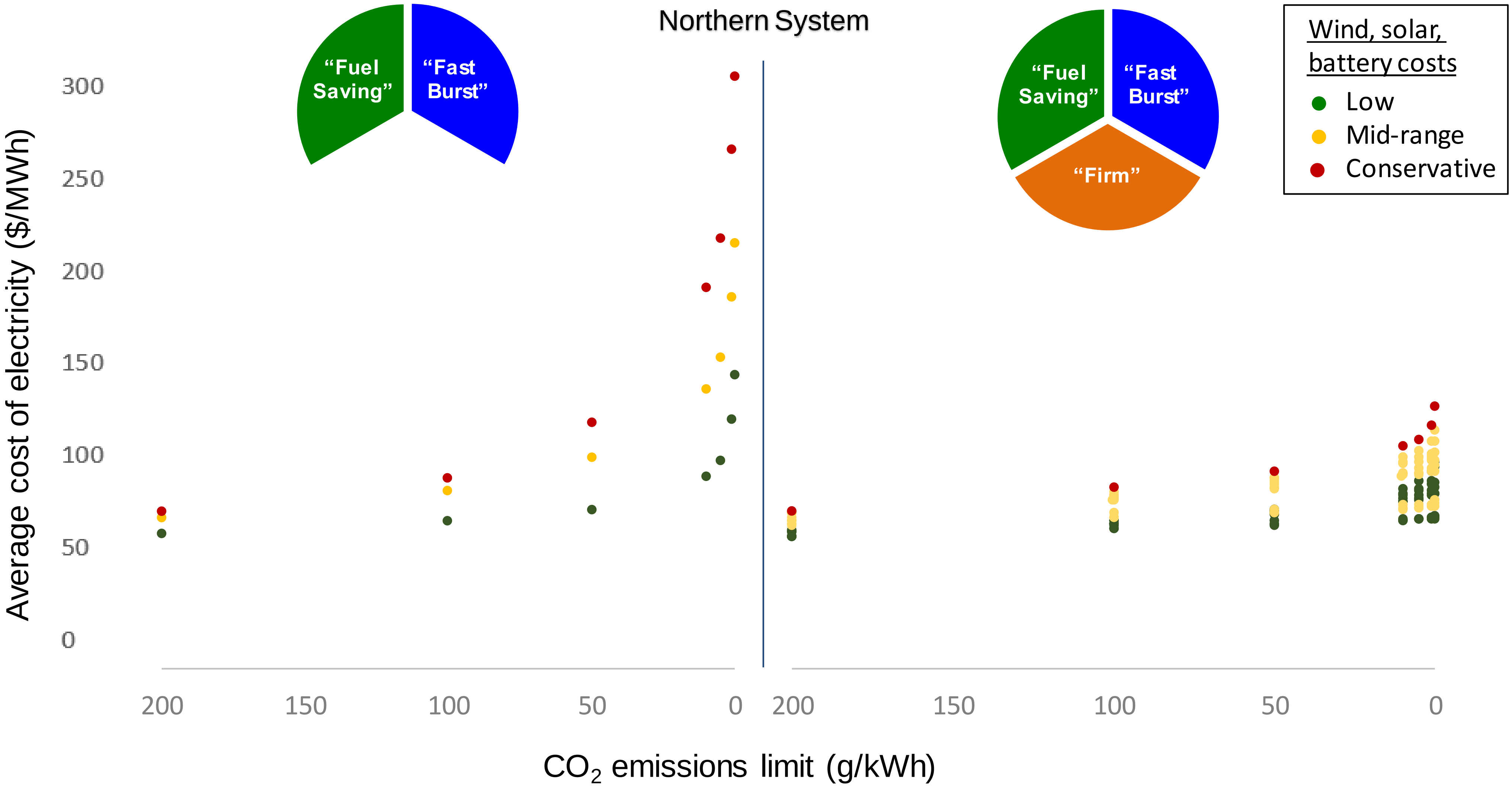
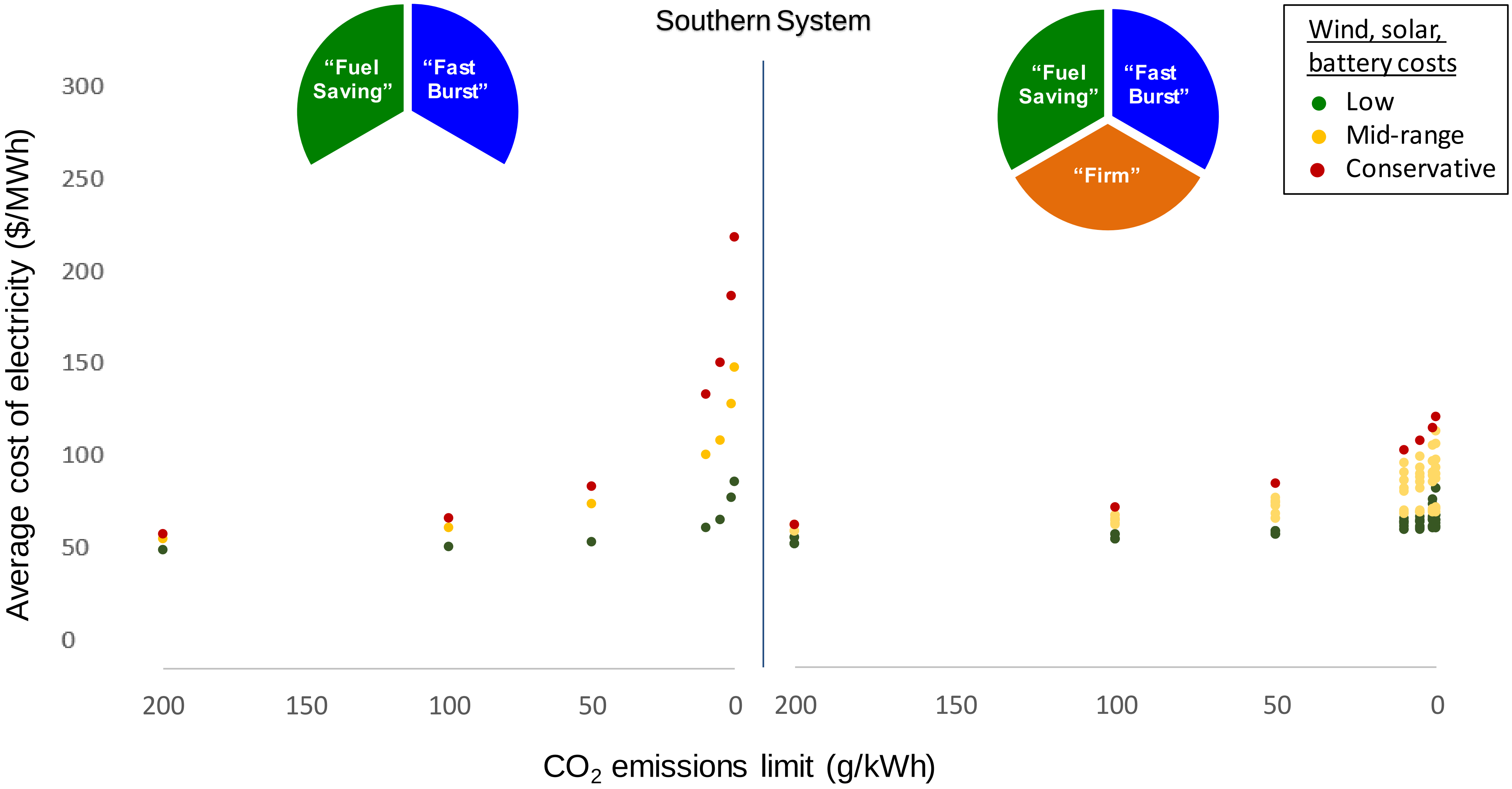

Solar PV
Solar thermal
Wind energy
Run-of-river hydro
Solar thermal with storage
Reservoir hydro
"Fuel saving" variable renewables
"Fast burst" balancing resources
Demand response (price responsive curtailment)
Flexible demand (rescheduling)
Battery storage
Long-duration storage
"Firm" low-carbon resources
Geothermal
Nuclear
"Flexible base"
Gas or coal w/CCS
Biomass
Biogas
"Firm cyclers"

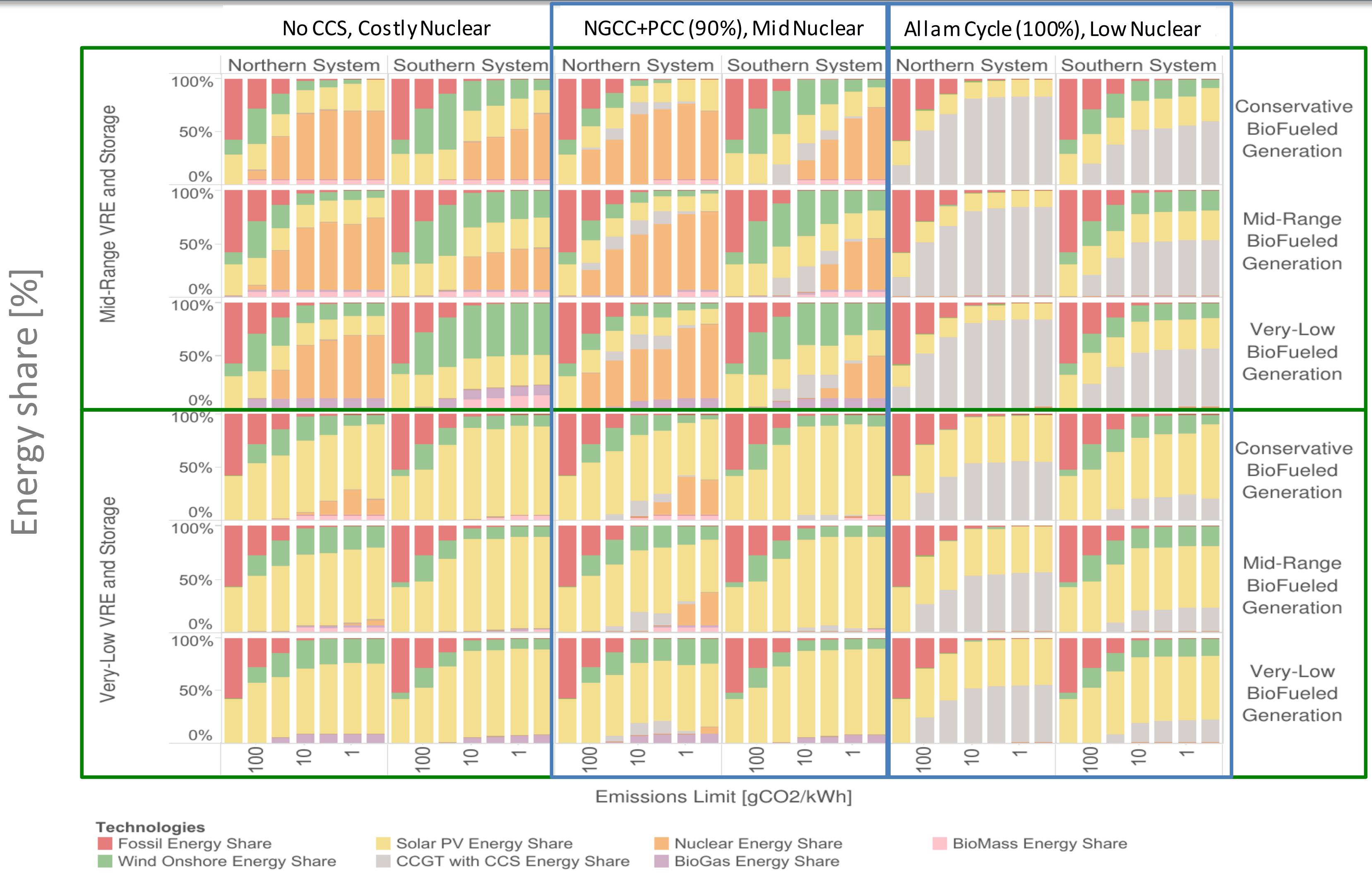


Data source: Sepulveda, N., Jenkins, J.D., et al. (2018), "The role of firm low-carbon resources in deep decarbonization of electric power systems," *Joule* 2(11).

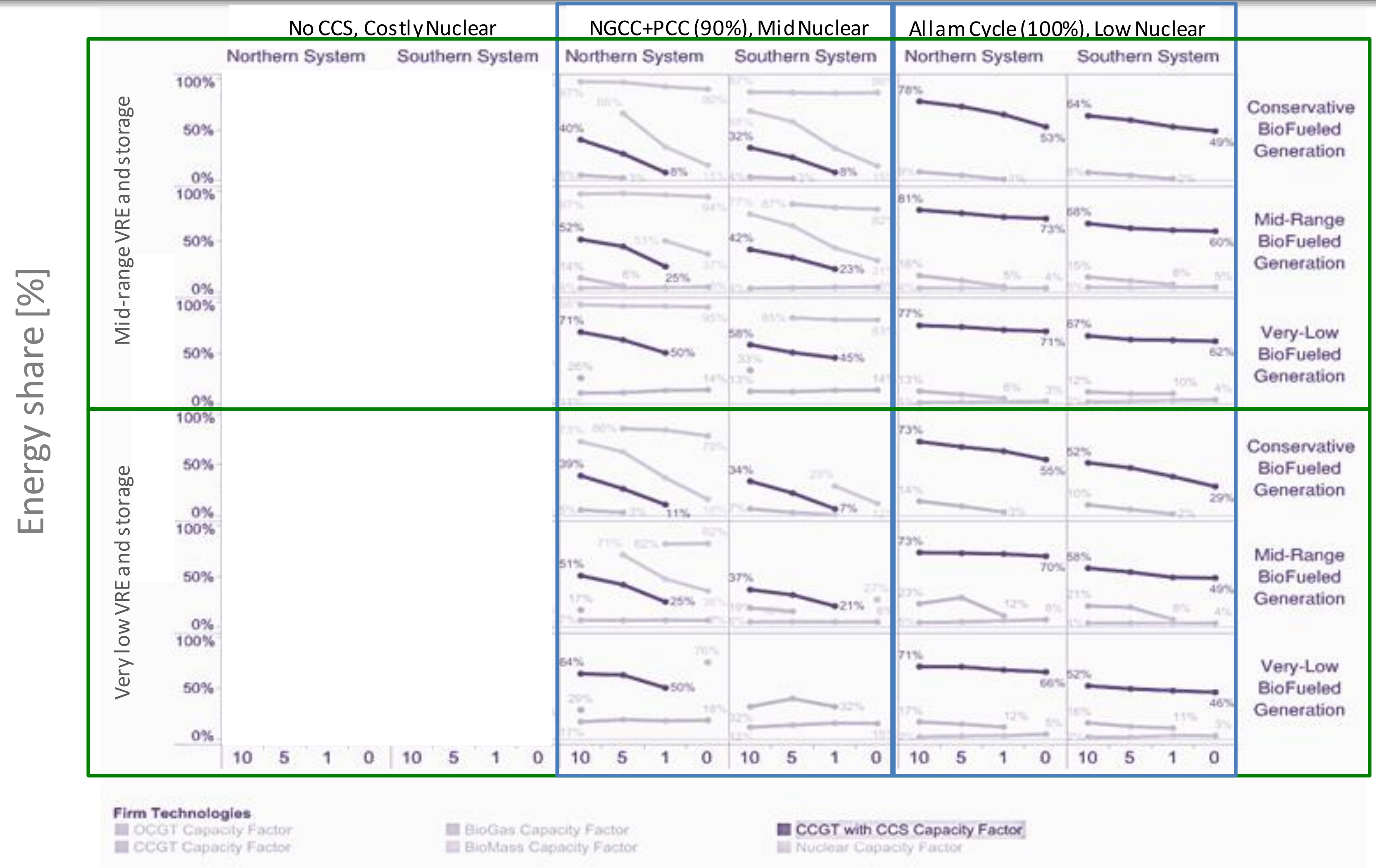


Data source: Sepulveda, N., Jenkins, J.D., et al. (2018), "The role of firm low-carbon resources in deep decarbonization of electric power systems," *Joule* 2(11).

NATURAL GAS WITH CCS MAY PLAY SIGNIFICANT ROLE

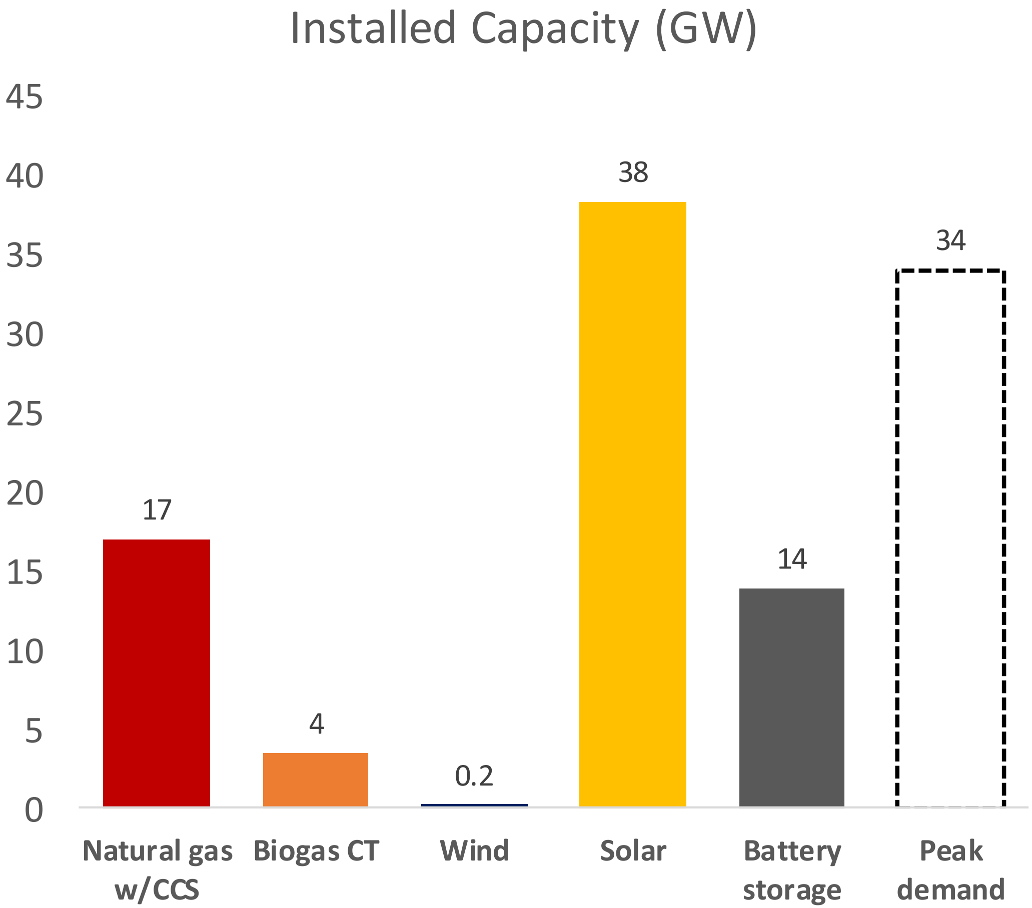


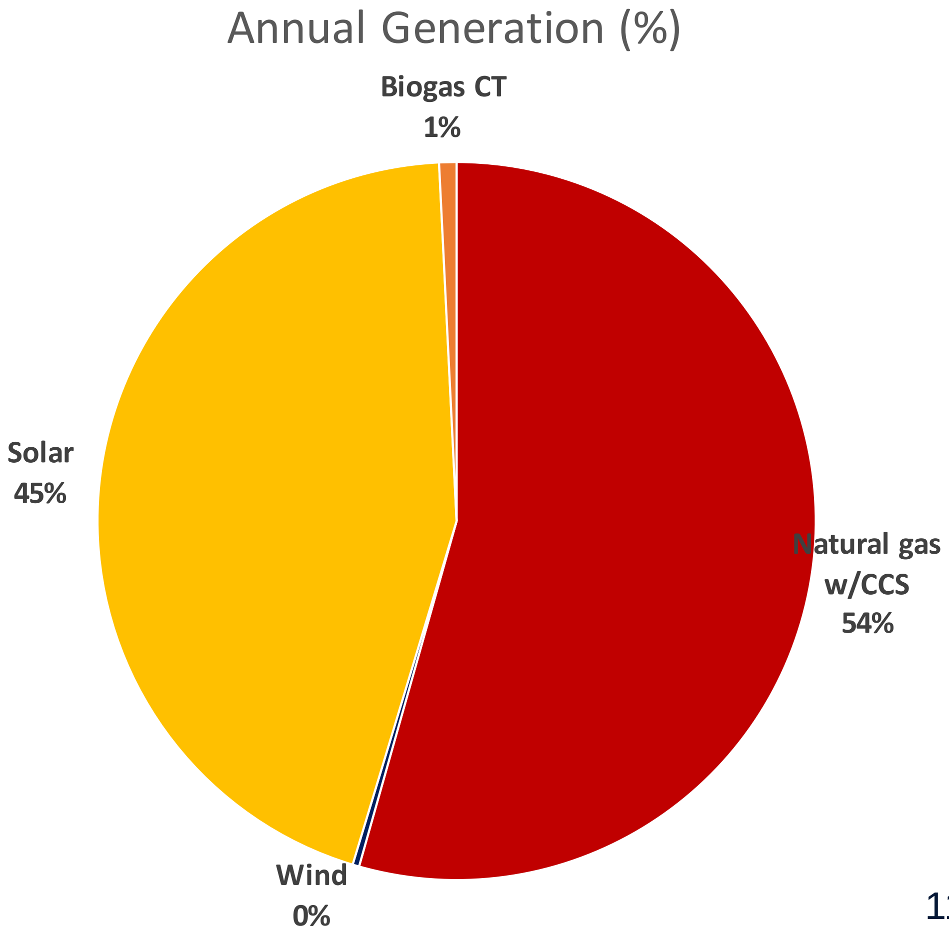
NATURAL GAS WITH CCS IS OPERATED FLEXIBLY



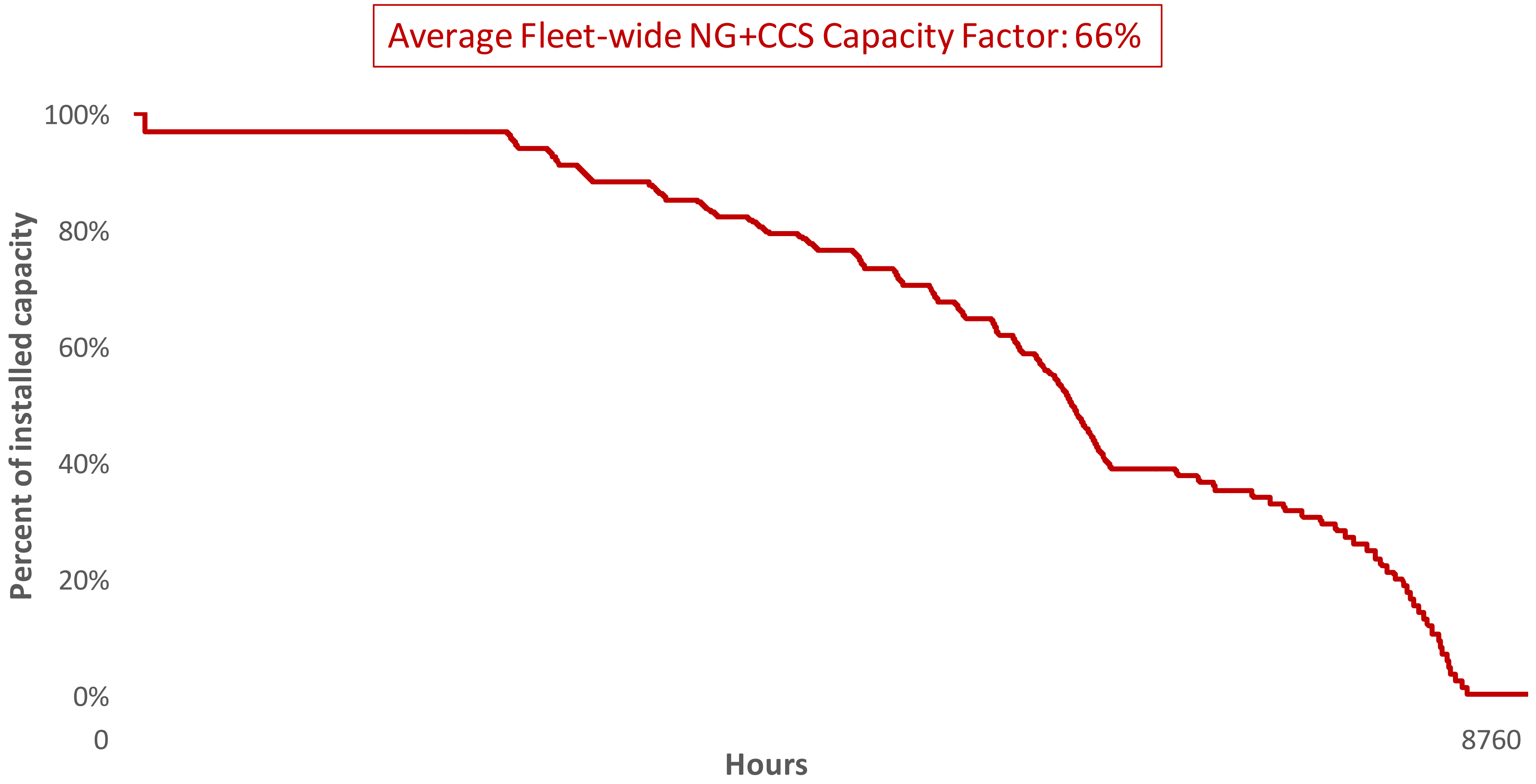
AN EXAMPLE OF FLEXIBLE CCS IN A ZERO CARBON ELECTRICITY SYSTEM

Detailed case results for Northern system, very low cost scenario for all resources

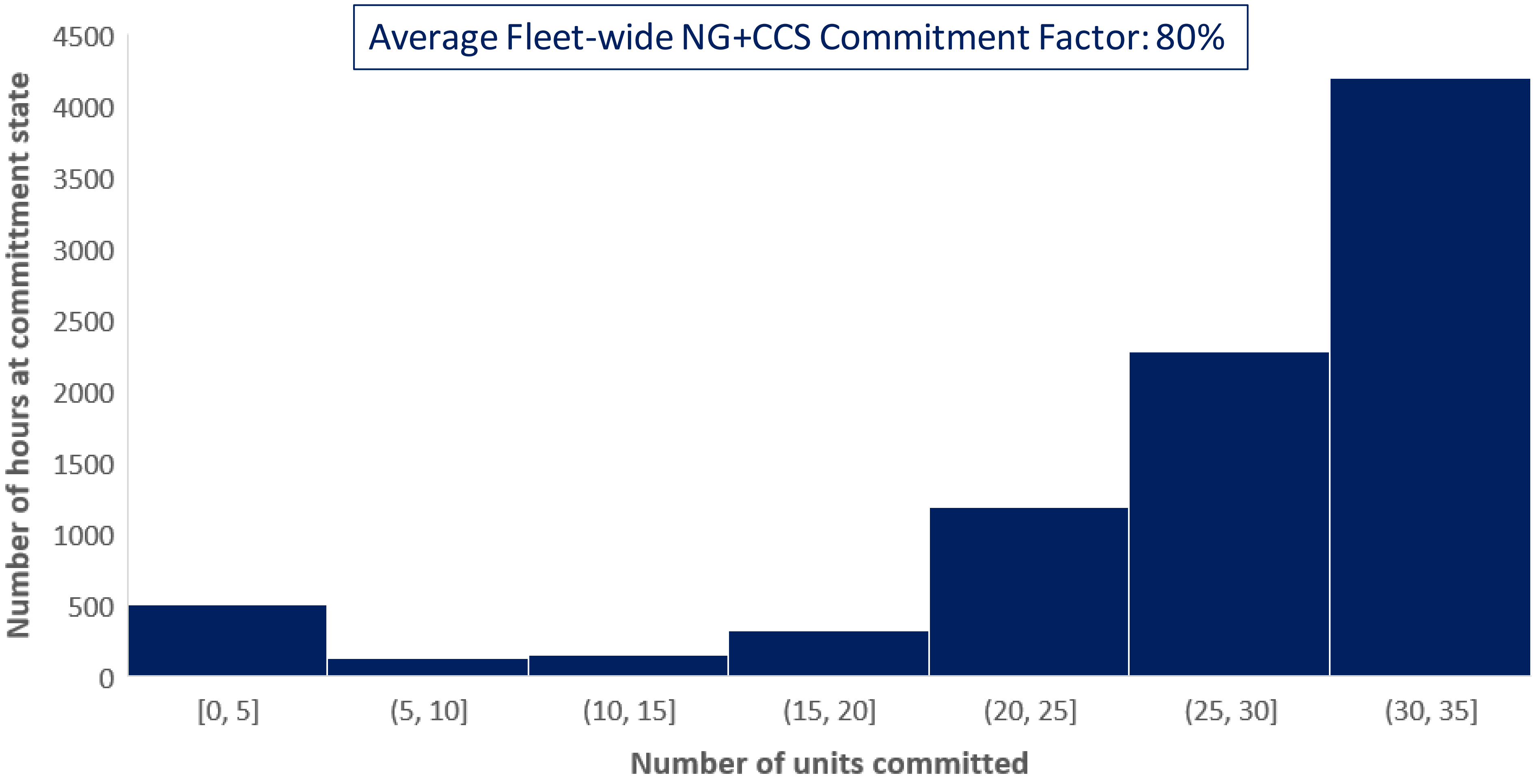




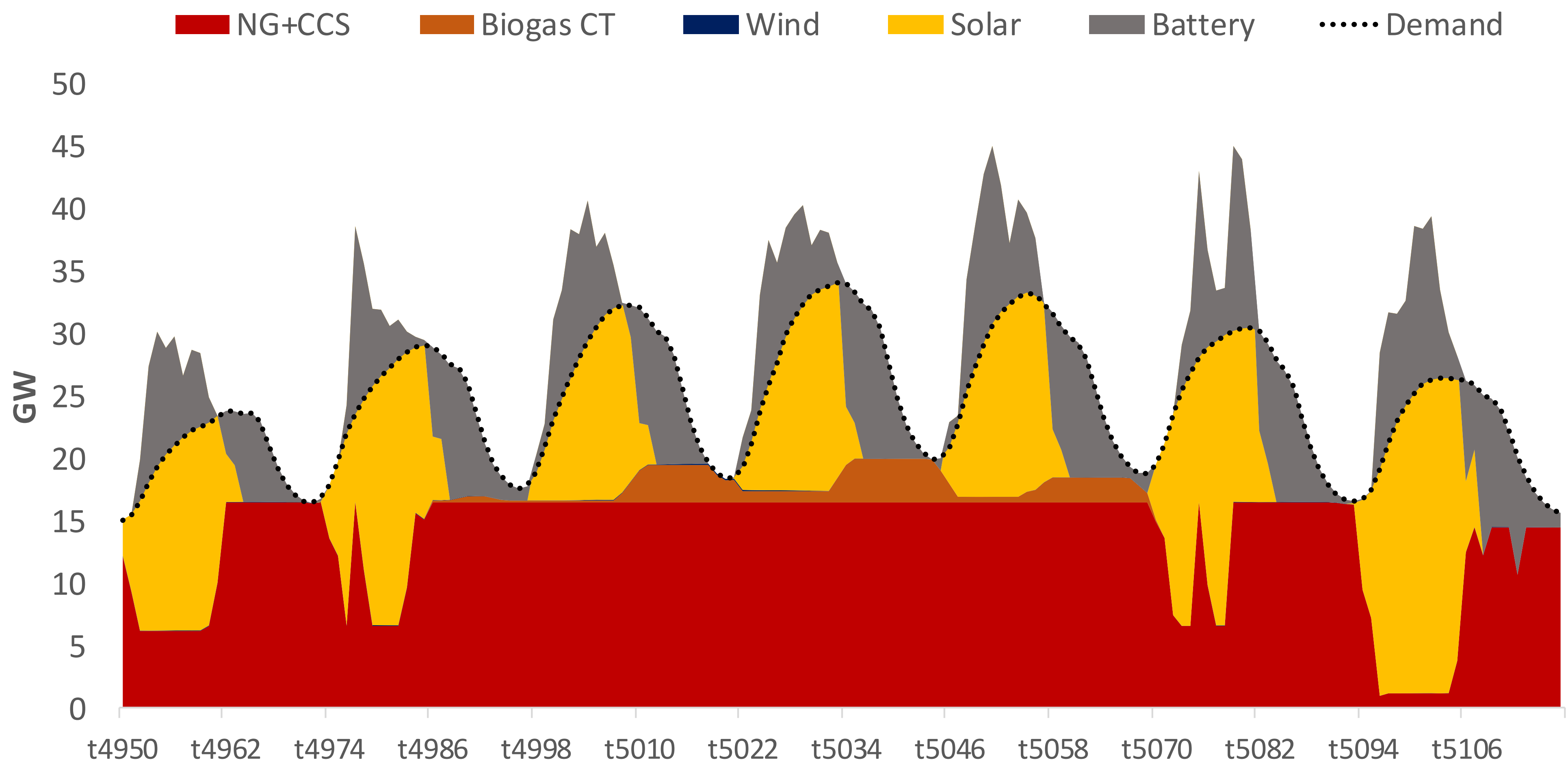
ANNUAL GENERATION DURATION CURVE



UNIT COMMITMENT DISTRIBUTION

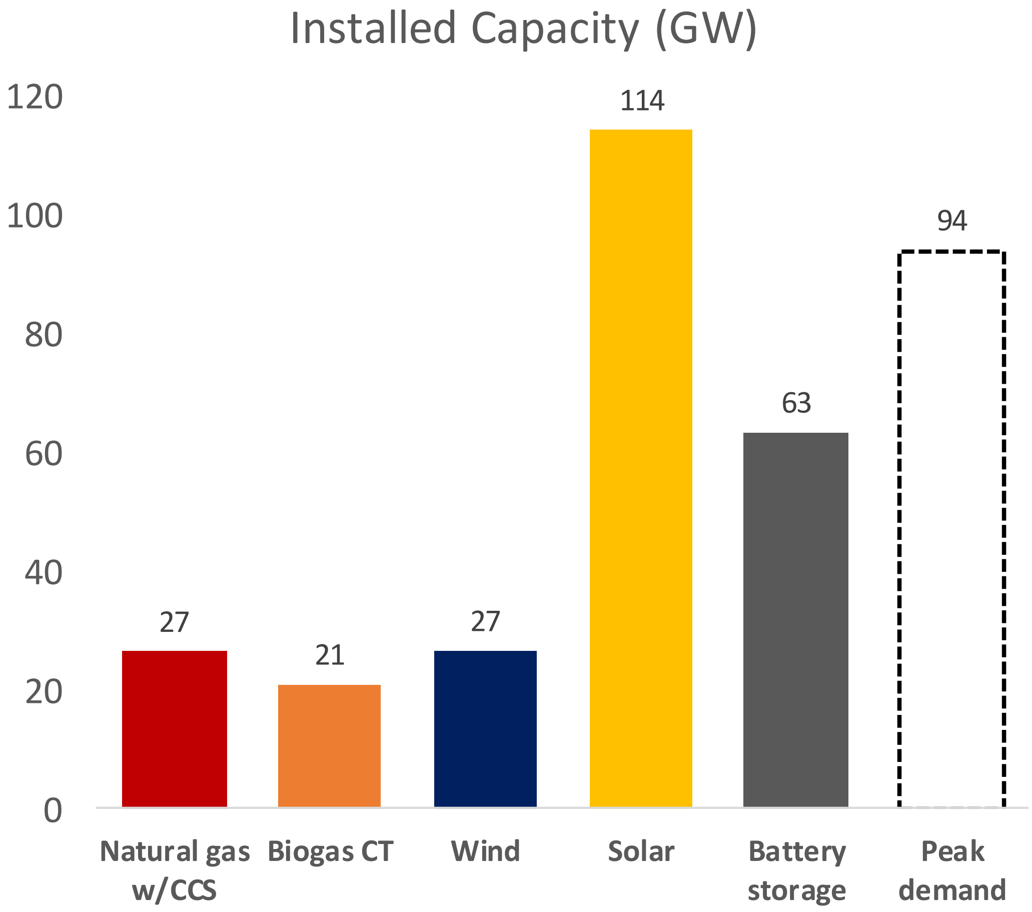


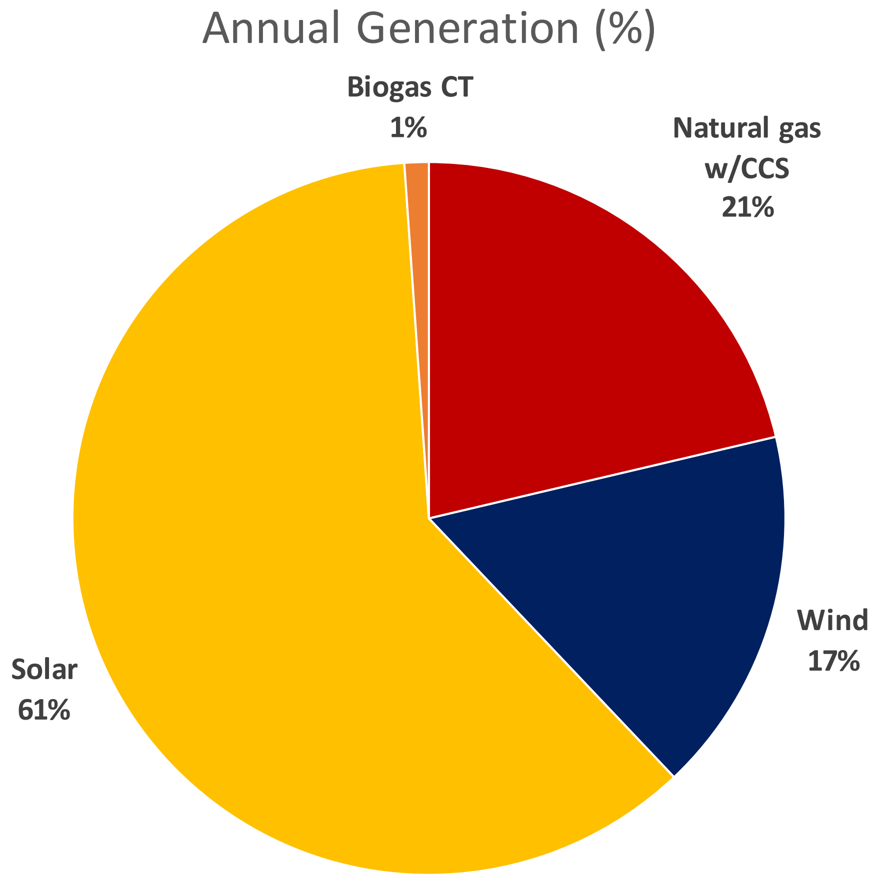
HOURLY DISPATCH DURING PEAK DEMAND WEEK (JULY)



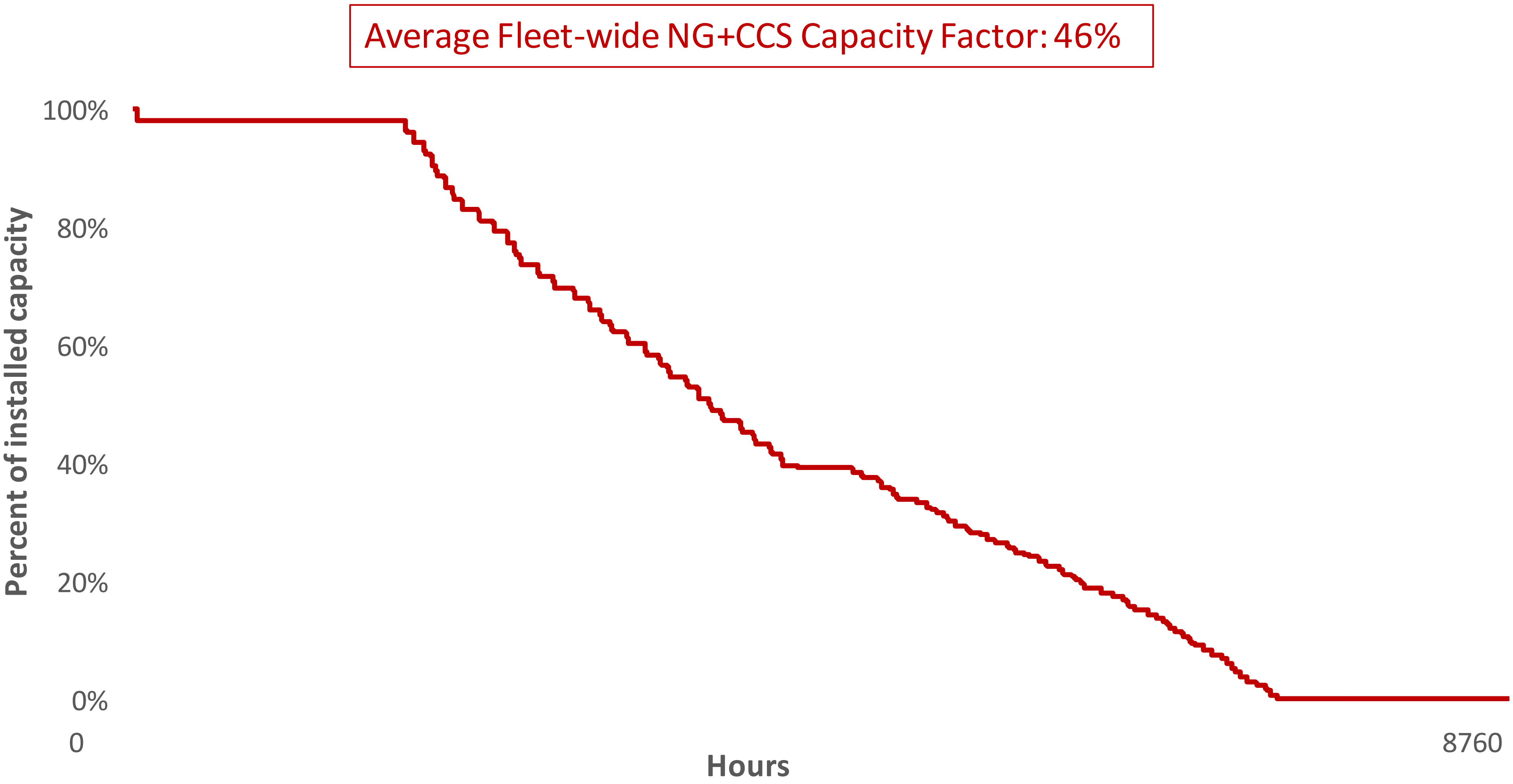
AN EXAMPLE OF FLEXIBLE CCS IN A ZERO CARBON ELECTRICITY SYSTEM

Detailed case results for Southern system, very low cost scenario for all resources





ANNUAL GENERATION DURATION CURVE



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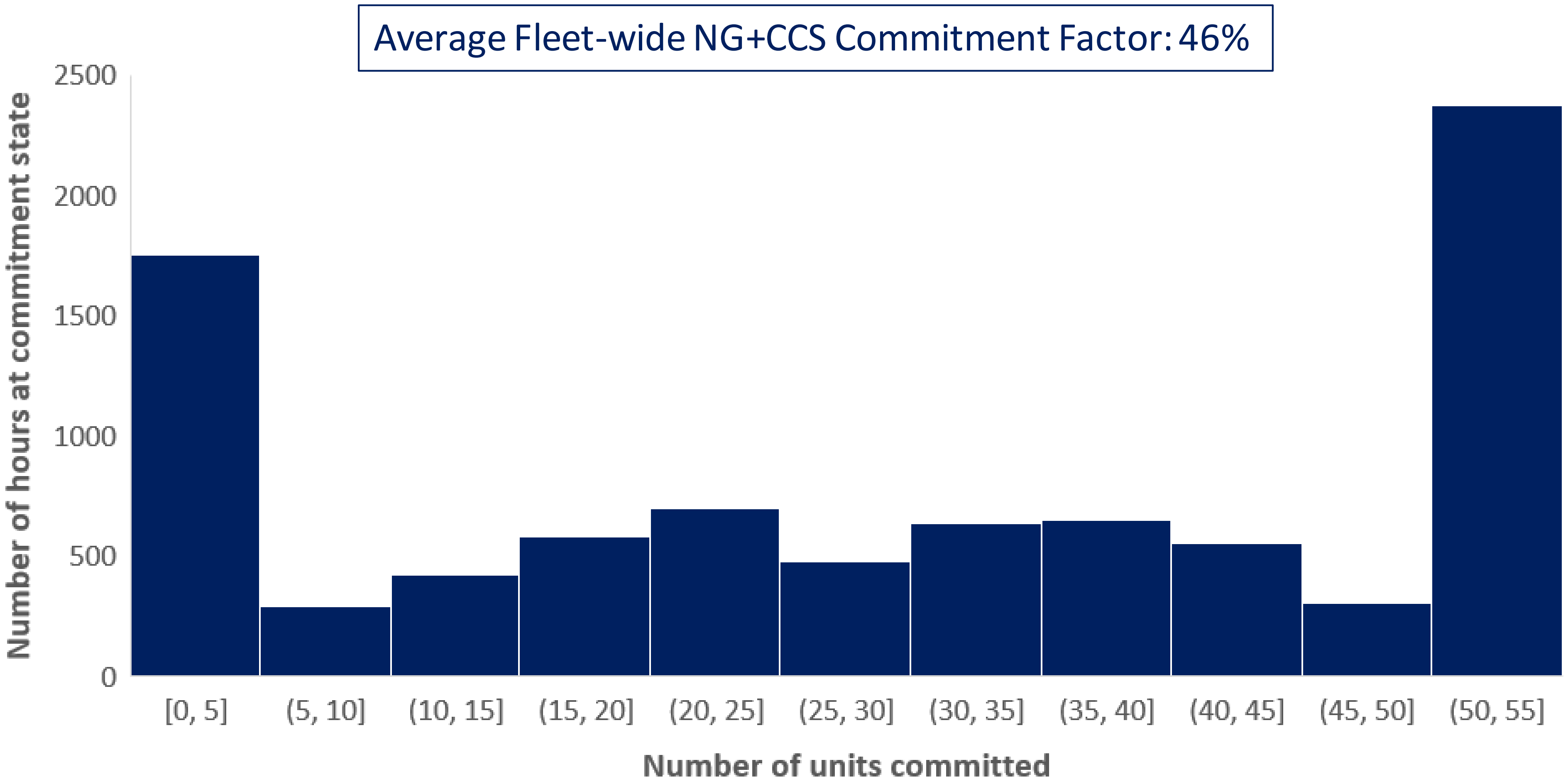
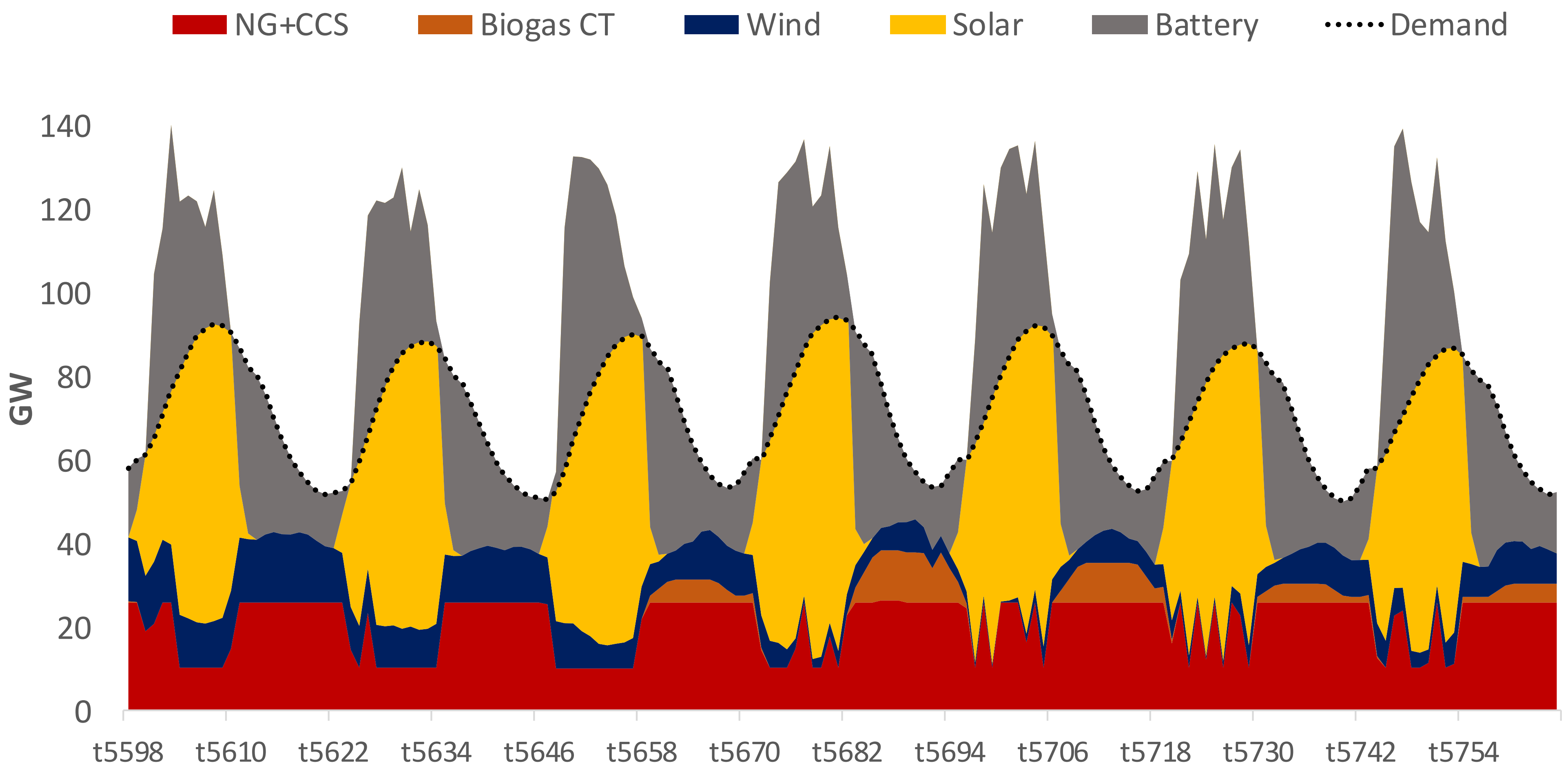


HOURLY DISPATCH DURING PEAK DEMAND WEEK (AUGUST)



SOME OPEN QUESTIONS

- What is the ideal “design space” for CCS from the electricity system perspective? What set of cost and performance characteristics are most attractive/make CCS most competitive?
  - Capital and fixed O&M costs; Capture efficiency; Heat rate; Ramping rates; Minimum turndown / stable output; Cycling costs; Cycling time
- How does availability of other competing or complementary resources (e.g. nuclear, storage, flexible demand, wind vs. solar heavy systems) affect the ideal design space for CCS?
- How valuable is it to de-couple parasitic loads for the capture process to enhance flexibility (e.g. storing oxygen for oxyfuel combustion, storing saturated amines for later CO2 removal)
- Is it valuable to have a variable capture rate (with tradeoffs in heat rate)? – Is it worth achieving a lower turndown level by increasing capture rate at a greater efficiency penalty vs. cycling off the plant?
- Are there cost-effective/competitive opportunities for coupling thermal or electrical storage?

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